

Original Research

Evolutionary Path of Responsible Research and Innovation: Opening the Black Box of RRI

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Abstract

In the new generation of entrepreneurial and community-based universities, their role in solving social issues and socializing has become much more essential. If universities and scientific institutions want to take action in this direction more than before, it is necessary to gain an accurate understanding of the insights and dimensions of social responsibility in research and innovation. In this study, we seek the main concepts in the field of Responsible Research and Innovation (RRI). We have opened the black box of it through systematic literature review(SLR) and Scientometrics Analysis(SA). This study shows that the Responsible Research and Innovation concept has been evolving in recent years with the development of scientific concepts such as social innovation, corporate social responsibility, and university social responsibility. In this study, the selected articles identified by the SLR method from different textual dimensions and the emergence of new concepts are analyzed. In this study, 33 concepts in 8 different themes in the black box of RRI were identified based on the SLR method. Also, based on the Scientometric analysis and word occurrences analysis, the 10 most used words were identified. Finally, through a collaborative review, 5 key concepts for this area have been identified. These concepts are public engagement, sustainability, ethics, governance, and RRI. Breaking the black box of this concept in this article can shed some light on the literature in this field and reduce its complexity.

Keywords: Responsible Research and Innovation (RRI), Black Box, Systematic Literature Review (SLR), Scientometric Analysis (SA), Public Engagement, Sustainability.

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Introduction

One of the most important issues in different societies is to determine the appropriate way of governing science and technology to realize the concept of responsible research and innovation. Accountability of universities and research institutes in developing countries, which are mostly government-oriented structures, is one of the challenges. The integration of this concept in the science and technology policy structures of these countries can lead to appropriate paths of development and reduction of society and industry issues.

Responsible research and innovation is a transparent and interactive process in which actors and innovators of society are held accountable based on acceptance (ethical), sustainability and social desirability, based on the process of innovation and marketable products. (In order to institutionalize scientific and technological advances in society) (René Von Schomberg, 2012; Rene Von Schomberg, 2013). While the origins of RRI date back to the early 1990s, the concept has received a great deal of attention since 2011 in the European Union (EU)'s policy and research communities (Owen, Macnaghten, & Stilgoe, 2012). The concept of RRI has been challenged by discourses on emerging technologies and research ethics in innovative fields(Owen & Goldberg, 2010). It has been driven by EU's research and innovation policy over the past few years(Auer & Jarmai, 2018). RRI can be considered as a concept that has been developed to expand the scope of policy-making, to show the path of innovation and to determine the role of actors in society (Burget, Bardone, & Pedaste, 2017; Levidow & Neubauer, 2014). The concept of RRI is an attempt to promote a new method of governance in the direction of research and innovation. This method has been described as "a way to think more systematically about the general benefits of scientific and technological research."(Baldwin et al., 2013; Timmermans, Yaghmaei, Stahl, & Brem, 2017).

There are several definitions of the main factors of RRI discourse. Von Schomberg defined RRI as "a design strategy that drives innovation and achieves the desired goals of society" (Rene Von Schomberg, 2013). Most researchers in the definition of RRI have emphasized von Schomberg's definition(Bremer, Millar, Wright, & Kaiser, 2015; Mohammadi & Babaei, 2022; Mohammadi & Mohammadi, 2021). Stahl (2013) considers RRI as a trans-responsibility that defines the concept as follows (Bisheh, 2022; Stahl, 2013):

"RRI is a macro-level responsibility or trans-responsibility that aims to shape, maintain, develop, coordinate and align existing and new processes related to research and innovation, actors and responsibilities in order to ensure desirable and acceptable research results "

RRI explicitly addresses issues of social development, social justice, and the extension of STI benefits. However, it is rarely articulated about this concepts in the subject literature (Ribeiro et al., 2018). RRI emphasize the importance of governance in innovation process (especially in the field of key stakeholders interaction and the need for inclusive and sustainable development) in the field of regional development (Thapa, Iakovleva, & Foss, 2019). Another important definition stems from another policy

document issued in 2013 (p. 3) by the European Commission (EC) entitled " Options for strengthening responsible research and innovation". In recent years, another comprehensive definition has been provided as follows:

RRI is a policy-driven discourse that has been grounded in the EC since 2011. At the macro level, its goal is to foster a comprehensive and sustainable research and innovation plan, with an emphasis on co-creation with society ("Science with society and for society") (Owen & Pansera, 2019).

Based on the EU's RRI Framework for Horizon 2020, RRI became a formal issue, and project funding began in the Science for Society program (now known as Science with and for Society). Therefore, in 2014, the mainstream RRI was introduced throughout the EU region through the "Rome Declaration on RRI" project (Thapa et al., 2019).

In this study, based on a systematic literature review(SLR) and scientometric methods, the growing path of the Responsible research and Responsible innovation in the literature is investigated. In this paper, new concepts in the field of responsible innovation and responsible research are analyzed by SLR and Sientometric analysis.

If the concept of RRI is to be considered as a concept recognized in other countries and other research initiatives and fields, it must be able to take significant relevant action. Participating and interacting with global science and technology actors and their distinct needs can work for nations where the RRI discourse is underdeveloped and not considered a priority. To be able to make innovation and research transparent and responsible (Macnaghten et al., 2014).

The EC described six distinct dimensions termed as follows: engagement, gender equality, science education, ethics, open access and governance ("Regulation (EU) No 1291/2013," 2013). Of course, the concept of ethics and some other related issues in science, technology, research and innovation is not a new topic in general, but the concept of RRI has recently been introduced to include responsibility in research and innovation policies and methods (Flick, 2016; Stilgoe, Owen, & Macnaghten, 2013).

Stahl (2013) focused his research on the practical implementation of the dimensions that arise for actors, norms, and activities. Various authors have referred to previous dimensions that were not originally associated with RRI (Stahl, 2013). Stilgoe et al. (2013) mentioned four dimensions that were raised during the general debates: anticipation, inclusion, reflexivity, and responsiveness. This framework for RRI focuses on four integrated dimensions(Stilgoe et al., 2013). This classification was adapted and adopted by the UK Engineering and Physical Sciences Research Council to form the AREA (anticipation, reflection, engagement and action) framework(Owen, 2014). Stilgoe et al, proposed a broader definition of RRI 'taking care of the future through collective stewardship of science and innovation in the present' in 2013 (Stilgoe et al., 2013).

Despite various studies conducted in the field of responsible innovations and researches, there has not been an appropriate study on the process of manuscripts production in this regard. The identification and scientometric analysis in this regard can

raise new insights on the research process of this field and the emergence of new concepts. These issues need further investigation and trying to be addressed in this study.

Methodology

In this paper, a comprehensive scientometric study in the field of responsible research and responsible innovation has been conducted. In the first step, ISI papers in related fields were extracted from the WOS database. In the next step, after initial screening and identification of related articles in terms of title, abstract and content, the final articles were analyzed based on an analytical-process package called "Bibliometrix" in R software. This analytical-process package is a tool for quantitative research in the field of scientometrics that is used for statistical analysis of articles extracted from citation databases. These statistical analyzes that have been used in this study have been in the fields of analysis of scientific collaborations of researchers, co-citation and synergies between scientific activities. These statistical analyzes have been performed on scientific collaborations of researchers, co-citations and synergies between scientific activities(Aria & Cuccurullo, 2017).

In the first search on the Web of Science citation database, the keywords "Responsible Research" and "Responsible Innovation" were searched. 861 articles were identified in English between 1990 and 2021. Then, in the first screening step, 648 articles were selected based on the subject area and journals. In this step, only articles related to management and social sciences were selected. duplicates were eliminated. Also, in the next screening, from the perspective of reviewing the title and abstract, 572 articles were finally selected for scientometric analysis in the field of responsible research and responsible innovation.

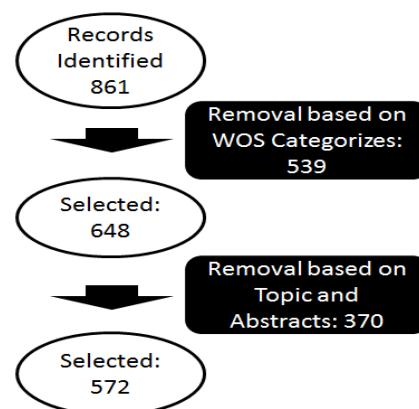


Figure 1. Flow diagram of article selection

Scientometrics is a tool for quantitative analysis and statistical evaluation of documents such as journal papers and the number of citations. Today, these analytical methods are used to assess the growth rate of concepts, leading authors, and the mind and concept maps of research. These tools can also be used to identify the evolution of scientific societies and evaluate research performance in various fields. The existence of effective statistical algorithms, access to quality numerical routines as well as integrated information imaging tools are the most important qualitative features that make

researchers prefer R programming language to other languages for scientific computing (Aria & Cuccurullo, 2017).

A. Descriptive statistics of selected articles

Based on the results of scientific search and screenings, the descriptive statistical information of the selected papers is presented in Table 1.

Table 1. The descriptive statistical information of the selected papers

Description	Value
Articles	572
Period	1990:2021
Average citations per documents	11.22
Authors	2037
Author Appearances	2411
Authors of single authored documents	121
Authors of multi authored documents	1916
Documents per Author	0.28
Authors per Document	3.52
Co-Authors per Documents	4.17

As shown in Table 1, based on scientometric analysis, 572 selected articles of this research were analyzed. Indicators of mean citation and co-authorship are also expressed. Out of 572 selected articles, 94 are related to the journal entitled: "Journal of Responsible Innovation". The 10 journals with the most selected articles in the field of social innovation and social responsibility are listed in Table 2 along with the number of articles included.

Table 2. The 10 journals with the most selected articles in the field of social innovation and social responsibility

Sources	Articles
Journal of Responsible Innovation	94
Science and Engineering Ethics	38
Sustainability	33
Nanoethics	29
Science and Public Policy	12
Technological Forecasting and Social Change	10
Research Policy	9
Ethics And Information Technology	8
Journal of Agricultural & Environmental Ethics	8
Science Technology and Society	8

The results of reviewing the references of 572 selected articles showed that 724 referenced articles were from the journal entitled: "Journal of Responsible Innovation".

There are also 619 articles cited in the journal entitled: "Research Policy". Table 3. shows the journals with the most citations.

Table 3. The summary of the most cited journals

Sources	Articles
Journal of Responsible Innovation	724
Responsible Iinovati	640
Research Policy	619
Science and Engineering Ethics	450
Science And Public Policy	409
Nature	313
Science, Technology, & Human Values	312
Sustainability	264
Public Understanding of Science	262
Technological Forecasting and Social Change	256

There are various software tools that help researchers analyze scientometrics, but some of them are much more widely used. Among them can be software tools are Biblioshiny (Mohammadi & Babaei, 2022).

Findings

In this section, with the help of scientometric tools, the growing trend of attention in the development of scientific manuscripts in the responsible research and responsible innovation fields is described. The interactions of different authors and their scientific achievements in this area in various journals leads us to identifying the new impression of emerging concepts in this area.

Based on the Co-Citation Network, researchers' citation network can be observed in the field of scientific production of responsible innovation and responsible research. Scientific articles of researchers such as Stilgoe, 2013, Owen, 2012 and Von schomberg, 2013 have the highest density in the rate of co-citation in the network. These articles promote strong networks around themselves by presenting the basis of scientific discussions on innovation and responsible research.

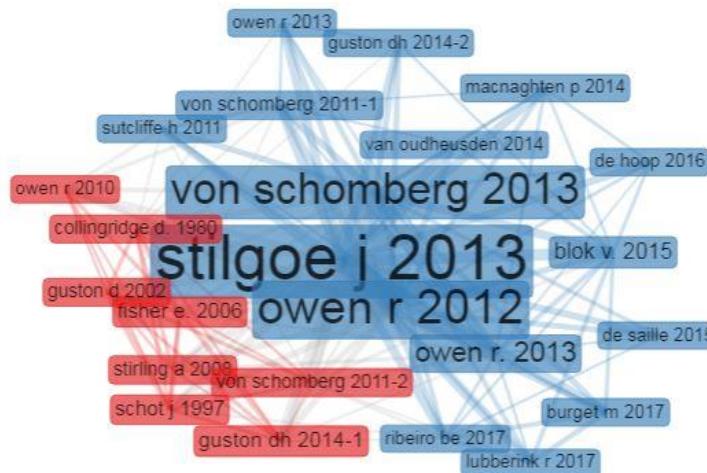


Figure 2. Co-Citation Network

Based on the keyword analysis of 572 selected articles, the results in terms of words occurrence are shown in Table 4. The new concept of "Responsible research and innovation" ranks first with 160 repetitions in articles. The keyword "Responsible innovation" has since been repeated 120 times. The keywords "Ethics" and "Governance" are also in the next categories.

Table 4. Words Occurrence in Selected Papers

Words	Occurrences
Responsible Research and Innovation	160
Responsible Innovation	120
Ethics	44
Governance	37
Nanotechnology	26
RRI	26
Innovation	25
Synthetic Biology	24
Sustainability	23
Public Engagement	22

Figure 4. obtained with the help of R software tools, shows well that in the scientific literature in the field of responsible innovation and responsible research, new concepts such as sustainability, ethics, public engagement, governance and innovation have been able to play more prominent roles. These issues can be very significant for relevant stakeholders at the relevant academic and executive levels.

Various concepts in recent research of universities and scientific centers are about sustainability proposed. Environmental innovation, sustainability innovation (Auer & Jamai, 2018) and regional sustainable development (Thapa et al, 2019) have been proposed by researchers in this field. Nowadays, considering ethics in research and the effectiveness of research ethics in solving social problems is very necessary (Decker et

al, 2018, Flick et al, 2015, Stahl, 2013, Van den Hoven et al, 2012, Decker et al , 2018). It has been suggested that communities (Ribeiro et al, 2018), different stakeholders (Timmermans et al, 2017) and finally the society (Levidow & Neubauer, 2014) participate in various studies. Table 5 shows the set of concepts identified from the systematic literature review and their classification into 8 themes.

Table 5. Identified Themes and Concepts based on SLR

Themes	Concepts	References
Sustainability	Eco-Innovation	Auer & Jamai, 2018
	Sustainability Innovation	Auer & Jamai, 2018
	Sustainable Regional Development	Thapa et al, 2019
Ethics	Dynamics of Ethics	Decker et al, 2018
	Sufficient Ethical	Flick et al, 2015
	Ethics	Stahl, 2013
	Integration of Ethical	Van den Hoven et al, 2012
	Global Ethics	Decker et al, 2018
Engagement	Society Engagement	Ribeiro et al, 2018
	Stakeholder Engagement	Timmermans et al, 2017
	Public Engagement	Levidow & Neubauer, 2014
Social Integration	Societal Alignment	Ribeiro et al, 2018
	Mutual Respect	Decker et al, 2018
	Mutual Understanding	Decker et al, 2018
Stakeholders Commitment	Overarching Commitment	Macnaghten et al, 2014
	Pledges to Broader Concerns	Stahl, 2013
	Higher Level Responsibility	Stahl, 2013
Governance in STI Transition	Socioeconomic Transformation	Thapa et al, 2019
	Governance of STI	Ribeiro et al, 2018
	Governance of Socially Controversial Technologies	Macnaghten et al, 2014
	The Sociotechnical Nature of Innovation	Wiarda et al, 2021
	Responsible Governance	Fosberg et al, 2015
	Work Packages on Ethical, Social & Legal Issues	Stahl, 2013
	Anticipant Governance	Sutcliffel, 2011
Synergy and Convergence	Community's Collective Productivity	Wiarda et al, 2021
	Science in Society	Decker et al, 2018
	Integrating in Organizational Routines	Timmermans et al, 2017
New Research Natures	Research Integrity	Stahl, 2013
	Awareness Structure	Stahl, 2013
	Professionalism	Stahl, 2013
	Social Goods	De Saille, 2014
	Networks of Responsibility	Timmermans et al, 2017
	Desirable Research Outcomes	Stahl, 2013

The degree of ability to develop social interactions is essential in conducting purposeful and effective research. Social alignment(Ribeiro et al., 2018). towards the relevant research, the existence of mutual respect (Mohammadi, 2021) in such research and finally the creation of mutual understanding (Forsberg, Shelley-Egan, Ladikas, & Owen, 2018) in these studies is very important. Also, the existence of commitment in various stakeholders, especially researchers, can significantly help the research to be more effective in solving social problems. Creating a comprehensive commitment(Macnaghten & Owen, 2011), the commitment to create more concerns about existing issues and having more responsibilities in relation to the situation (Stahl, 2013), fall within the scope of these commitments.

The transition in science, technology and innovation will require more complex governance in the new context. In this regard, various researchers have proposed various concepts and discussed their characteristics and different conditions. Socioeconomic Transformation (Tavakoli, Babaei, & Sajadieh, 2020; Thapa et al., 2019), Governance of STI (Babaei & Tavakoli, 2017), Governance of Socially Controversial Technologies (Macnaghten & Owen, 2011), The Sociotechnical Nature of Innovation(Liang & Wang, 2021), Responsible Governance (Forsberg et al., 2015), Work Packages on Ethical, Social & Legal Issues(Stahl, 2013), and Anticipant Governance (Rene Von Schomberg, 2011) are among them.

Convergence and synergy in research are also necessary to enhance the role of science in society and increase collective productivity (Forsberg et al., 2018). Of course, this requires that research results be integrated at different organizational levels in society (Timmermans et al., 2017). To succeed in increasing the effectiveness of research in solving social issues, it is necessary to pay attention to the different nature of science and responsible research (Davies & Horst, 2015).

Conclusion

This study has generally been done on the emergence of new concepts and evolution of concepts related to responsible research and innovation. In this article, we have also stated the managerial implications for implementing these concepts in scientific institutions. Examining the challenges of implementing innovation models and responsible research in educational and research institutions and policy making related to them can be considered as complementary axes in future studies. Identifying the mechanisms and processes of implementing RRI and designing appropriate managerial functions is also suggested as future research in this field.

One of the most important aspects of RRI is to create a new model for the Science and technology governance. The main question of the present article is what are the new scientific concepts and paths for the realization of RRI? What are the practical and managerial conditions for the rule of science in the framework of RRI? And with what changes can these conditions be met in the governing system of universities? Our research on responsible innovation and responsible research outlines their overall approach to how science's responsibilities take precedence over social, moral, and environmental values. The ultimate goal of the development of this field of literature is to create a common responsible paradigm between science, policy-making and society in all elements of

society so that all people can enjoy the benefits of science and technology in a balanced way (EU, 2020). One of the most important issues that researchers and policy makers now face is the development of theoretical and creative ideas of RRI into practice and the responsibility implementation in the field of research and innovation. This study is also designed to help these researchers and policy makers in clarifying the path of operationalization of ideas to operationalize the responsibility of science and technology. Achieving this goal has been done by reviewing the results presented in recent years in this regard based on scientometric analyzes. Therefore, in order to research and policy in the field of research and responsible innovations, emerging scientific paths have been identified and introduced based on paper analysis. Understanding emerging concepts in the literature can design different and new paths for researchers and policy makers to design patterns and processes for research responsibility. The EC has also emphasized the need for new structural, executive and operational perspectives in this regard by introducing the concept of new patterns of scientific governance based on RRI. Accountability of educational and research centers, including universities and research institutes, along with the need for the participation of different sections of society, are general principles that emphasize the creation of new models of governance in RRI.

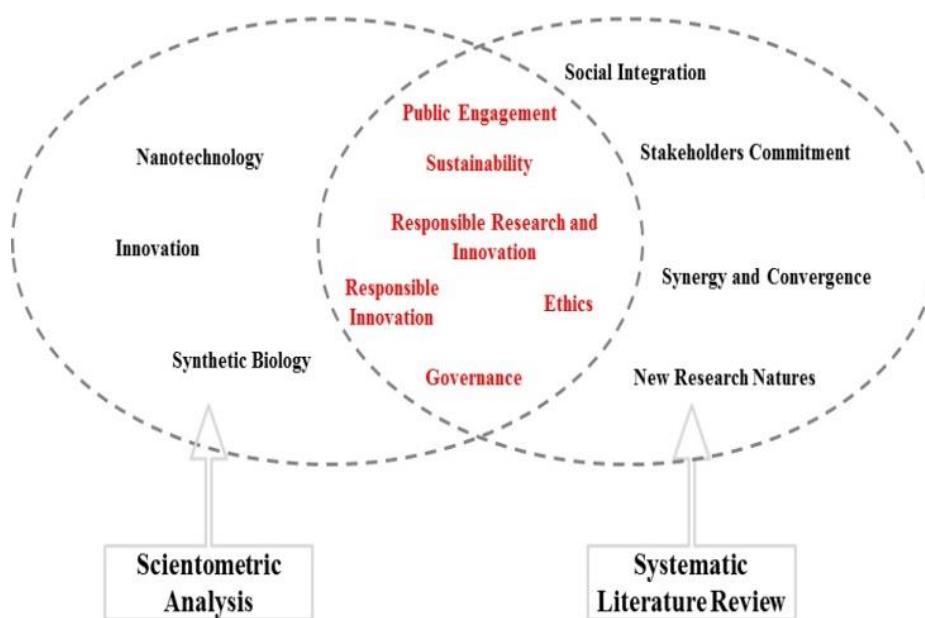


Figure 5. Concepts identified through SLR and Scientometric Analysis

Figure 5 shows the results of the study of concepts in the field of responsible research and responsible innovation in universities and scientific centers. The concepts shown in red have been identified as key concepts in the field of responsible research and responsible innovation, both in terms of Biblioshiny analysis and in terms of systematic literature review and duplicate code extraction. These include social participation, research ethics, and the various dimensions of the governance of science, technology, and innovation, sustainability, and responsible research and innovation (RRI).

This study has generally been done on the emergence of new concepts related to RRI. In this article, we gain insights to better conduct RRI in our societies for implementing

these concepts in scientific institutions. Examining the challenges of implementing innovation models and responsible research in educational and research institutions and policy making related to them can be considered as complementary axes in future studies. Identifying the mechanisms and processes of implementing RRI and designing appropriate managerial functions is also suggested as future research in this field. first of all, based on the SLR method, identified scientific articles in the field of responsible innovation and responsible research from the WOS database. Then, with screenings and selection of 572 articles, the second step was performed based on the steps of analysis using scientometric tools. With the introduction of the above concepts from the EU in recent years, today, the field of RRI has expanded rapidly in developing Asian countries as a growing necessity. This issue should be considered at the academic level as well as the relevant executive levels in different countries. RRI is one of the newest areas that is now widely discussed by researchers in the field of science, technology and innovation (STI) studies. Some researchers have introduced this concept as a new paradigm shift in the field of science, technology and innovation studies (Roco, Harthorn, Guston, & Shapira, 2011). Our research on responsible innovation and responsible research outlines their overall approach to how science's responsibilities take precedence over social, moral, and environmental values. The ultimate goal of the development of this field of literature is to create a common responsible paradigm between science, policy-making and society in all elements of society so that all people can enjoy the benefits of science and technology in a balanced way (Parliament & Union, 2013).

In this study, based on the SLR method, 33 concepts in 8 different themes for responsible research and responsible innovation were identified. Also, based on the scientometric analysis and word occurrences analysis, the 10 most used words were identified. Finally, through a collaborative review, 5 key concepts for this area have been identified and introduced. These 5 concepts include public engagement, sustainability, ethics, governance and RRI.

The results of this study show that significant changes in the exploration of research are underway. The emergence of the RRI concept also emphasizes the same. Of course, these concepts are interacting with each other and has many shares. But what is clear is the growing process of attention to these concepts. This issue is also growing in developing countries. New concepts in different areas of social engagement, citizen sciences, ethics and social responsibility are growing more than other areas. Therefore, the result of this study shows that scientific production based on this social need is grow.

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